Paper airplane game to introduce lean principles

Goals and takeaways:
- Participants will be able to compare the effects of functional work station layout with product layout (when the activities are arranged in the order of production steps).
- Push and pull approach will be compared.
- Participants will understand the basic philosophy of kanban method.
- The advantages of one-piece-flow (OPF) will be demonstrated.

What you will need (materials and accessories):
- 200 sheets of A4 (or B4) size paper – use recycled paper, if possible
- 12 coloured sheets of A4 (or B4) size papers for „hot" orders (optional)
- 20 punched pockets ("containers"); alternatively, letter clips can also be used
- 20 pieces of small (e.g. 2"x2") post-its
- 1 marker pen (to mark raw material for "hot" orders) and to write on the board
- 2 stopwatches (smart phones are also fine) – or project an electronic stop-watch
- 1 printed timelog template – if not the built-in stopwatch is used
- 1 projector or big screen TV set or white board

Preparations:
- Write the measures on the boards (unless you project those): measures plus 4 additional columns with the headings: push, pull, OPF, best
- „Hot" orders: unless you use coloured papers, just cross white papers with marker pen on both sides
- To mark incoming and outgoing areas at each workstation, write IN and OUT on post-its, plus the number of workstation; you can also combine information like that: IN-3, OUT-3
- The best is to arrange tables in U-shape (materials handler moves around inside the U), but other arrangement is also OK, just make sure to have enough space on the tables and for the materials handler
- One workstation:
    - IN: incoming storage, A4 size, standing
    - folding workspace for the operator: in front of her
    - OUT: outgoing storage, A4 size, standing

Introduction:
- Explain the situation:
    - The small company is manufacturing UAV (Unmanned Aerial Vehicle) bodies for professional, non-military purposes
    - Their customer wants to get the UAVs at low cost, excellent quality and in time (even better: on time)
    - The customer also requires flexibility, so that special orders are quickly fulfilled
    - The goals of the company: short throughput time, high labour productivity, high profit and positive cash flow
- Show how to fold the product: paper airplane folded in four phases (see the figures below)
    - first fold (half)
    - nose fold #1
    - nose fold #2
    - wing fold
- Review the production run (FIFO, expediting is not allowed)
- Everyone gets a piece of paper to practice (not only those, who will play)
- Review the roles, pre-select the participants for these roles

- Ask the operators to fold another airplane – note who are slower than others
- Assign the operators to the workstations (tip: put the slow operator to the 2nd or 3rd workstation)
- Quality:
  - miss-folded products are counted defective
  - if the wing is wider, than two times the height of the trunk, or narrower, than the height of the fuselage, the airplane is also considered defective
  - no rework
- Explain the measures and write them on the board (if you have not done so earlier)
- Confirm, that everybody understand the rules and roles

| 0. | 1. | 2. | 3. | 4. |
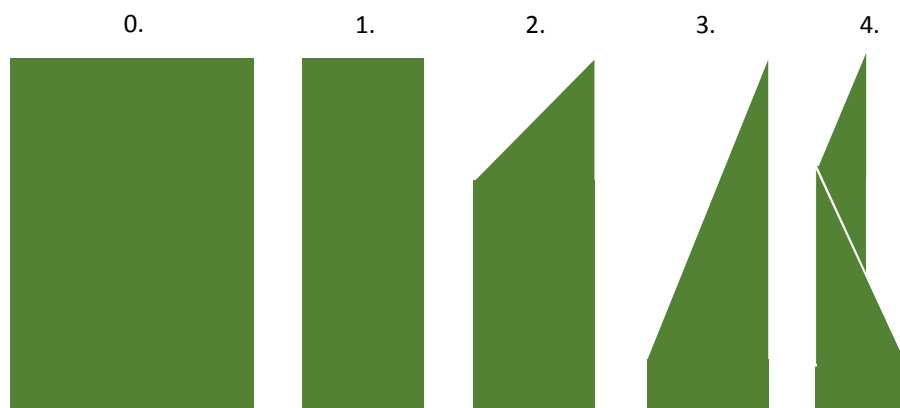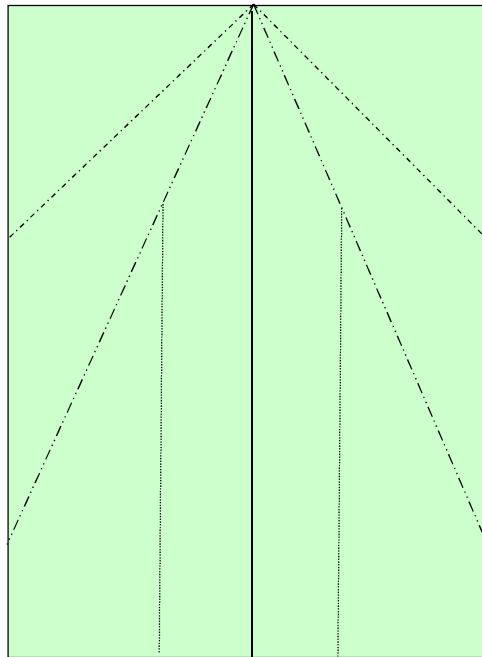
Roles (besides the facilitator):
- 1 Supervisor: helps keeping the rules, urges those who are slow, helps solving problems, counting products and collecting measures
- 1 Warehouseman: serves the first workstation with materials
- 4 Operators
- 1 Materials handler: moves around WIP and the final products
- 1 Quality inspector:
  - discards defective products
  - signals the receipt of hot orders

- 1 Customer:
  - pulls the products (only in the 2nd and 3rd run)
  - rechecks the products
  - preferably sits next to the quality inspector
  - not absolutely necessary, can be the same person, as the quality inspector
- 1 Timekeeper:
  - signals the start and end of the game and the times to launch the hot orders
  - records the start and receipt of hot orders, calculates average throughput time
- Observers (divided into two groups):
  - observation of wastes (primarily the 7 muda, plus unevenness and strains)
  - observation of system level problems, flow, moral, other people issues, utilization, etc.

Roles	Push 3			Pull 3			OPF		
	min.	best	max.	min.	best	max.	min.	best	max.
Total	**8**	**12**	**15**	8	12	15	7	9	12
Supervisor	1	1	1	1	1	1	1	1	1
Warehouseman		1	1		1	1			
Materials handler	1	1	1	1	1	1			
Operator	4	4	4	4	4	4	4	4	4
Quality inspector	1	1	1	1	1	1			
Customer		1	1		1	1	1	1	1
Timekeeper	1	1	2	1	1	2	1	1	2
Observer		2	4		2	4		2	4

The absolute minimum number of players is 7 – in this case the facilitator should take over a simple role, such as timekeeper or warehouseman. In case there are more than 15 trainees, the best idea is to form two groups, who will play simultaneously (in that case you will need twice as many materials).

You can use a template like this to record time:

Production run:	Start	End	Duration (sec)
Game	0:00	6:00	360
First hot order	2:00		
Second hot order	3:00		
Third hot order	4:00		
Average throughput time	--	--	

Metrics:
- Batch size: the number of products in one container /pc/
- Duration of production run: each lasts for 6 minutes /min/
- Throughput time: calculated as an average, if possible /min/
- Good pieces delivered to the customer /pc)/
- Rejects /pc/
- WIP: work-in-process from the work area of the first operator to the OUT area of last operator /pc/
- Cash flow: 10.000 euro for each finished products minus 5.000 euro for each defective products and pieces of WIP /euro/

- Workers: the number of workers in the workshop – their name is shown in bold in the above table /No./
- Productivity: the number of delivered airplanes divided by the number of workers /pc ÷ workers/

1. run: workstations are arranged randomly, push, 3 pc in a batch
- Placement of operators: the workstations should be in random order (not $1 - 2 - 3 - 4$)
- Storage areas: IN is to the left, OUT is to the right of operator (following Toyota practices)
- Operators: tell them, that they will be evaluated based on their personal performance
- Fill in the system: each workstation should have three pieces of paper in one „container" (slided into a punched pocket, or clipped together) in both the IN and OUT areas
- The airplanes should be in the proper phase, so as everyone will be able to continue working later according their role (e.g. the 2nd operator should have three airplanes in phase 1 in the IN area, and three more in phase 2 in the OUT area)
- The Timekeeper should make the necessary preparations
- Prepare papers for the „hot" orders
- The Timekeeper starts the stopwatch and shouts: „start", so the production run starts
- The Warehouseman continuously supplies the first operator with materials (1 container and three pieces of paper – it is fine just to place the papers onto the punched pocket in the IN area of the 1st operator)
- The Materials handler continuously transfers the containers (with the three airplanes inside) to the next operator
- Any number of containers are allowed in the IN and OUT areas (push production)
- 2, 3 and 4 minutes after the start of the production run the Timekeeper shouts: „hot order"
- The Warehouseman at these moments replaces one white paper with one coloured or crossed in the IN area of the 1st operator
- When the hot order arrives at the Quality inspector, she shouts: „hot order arrived", and the Timekeeper records the time
- 6 minutes after the start of the game, the Timekeeper shouts: "stop", and everyone should finish working immediately
- The supervisor will count the WIP, the defective pieces, while the Customer counts good finished products
- Data are recorded and the metrics are calculated
- During the closing discussion, answer the following questions and discuss the production run:
  - What have participants observed regarding the process?
  - What were their feelings, their subjective opinion?
  - What kinds of wastes were identified?
  - Can the process be improved, can the wastes be eliminated?

2. run: workstations are arranged randomly (as before), simple kanban (pull), 3 pc in a batch
- This run is very similar to the previous one, with some exceptions
- In the IN and OUT areas only one container is allowed
- It means, that until the Materials handler doesn't move a container from the OUT area of operator A to the (empty) IN area of operator B, operator A must stop working (only one container can be finished, which stays in the work area, until the OUT area becomes free)
- The same applies to the Quality inspector
- The Customer will try to pull one container from the OUT area of Quality inspector every 30 seconds (late "deliveries" are accepted), that means up to 36 airplanes can be „pulled" during a 6 minutes production run
- Therefore the takt time is 10 seconds
- Participants can be exchanged, but it is usually a better idea to leave everyone in its original position / role

- Fill in the system, just like during the pull game – you can use the WIP produced previously, but discard the surplus, and make sure, that there are no coloured airplanes / papers
- Everything else is the same, as in the previous run
- After finishing this run, ask the previous question plus compare the two runs
- Also discuss what differences this simple pull / kanban mechanism made

3. run: one-piece-flow (OPF)
- The operators and customer sit next to each other, in the order of production steps
- Materials comes from the left
- The pieces are transferred one by one, from hand to hand (no storage area – that is a strict OPF situation)
- Containers are not used
- No need for Warehouseman, Materials handler and Quality inspector (operators don't pass and don't accept defective items)
- When filling in the system, make sure that every operator has just one piece in front of her, in the proper phase, so as everyone can perform their assigned job
- The customer „pulls" one finished airplane every 10 seconds from the last operator
- Everything else is the same, as in the previous run
- In the last column mark the number of production run, which produced the best result – in all relevant cases, that should be the OPF
- Ask the usual questions and compare the differences of the 3 production runs
- Review the principles of push and pull production, and OPF

This document contains all the information to play successfully the game. However, if you want further support in the *form of an Excel file*, you can ***download it for free*** from the website (www.leansimulationgames.com).